1/98 IMOS WORKSHOP

presentation by

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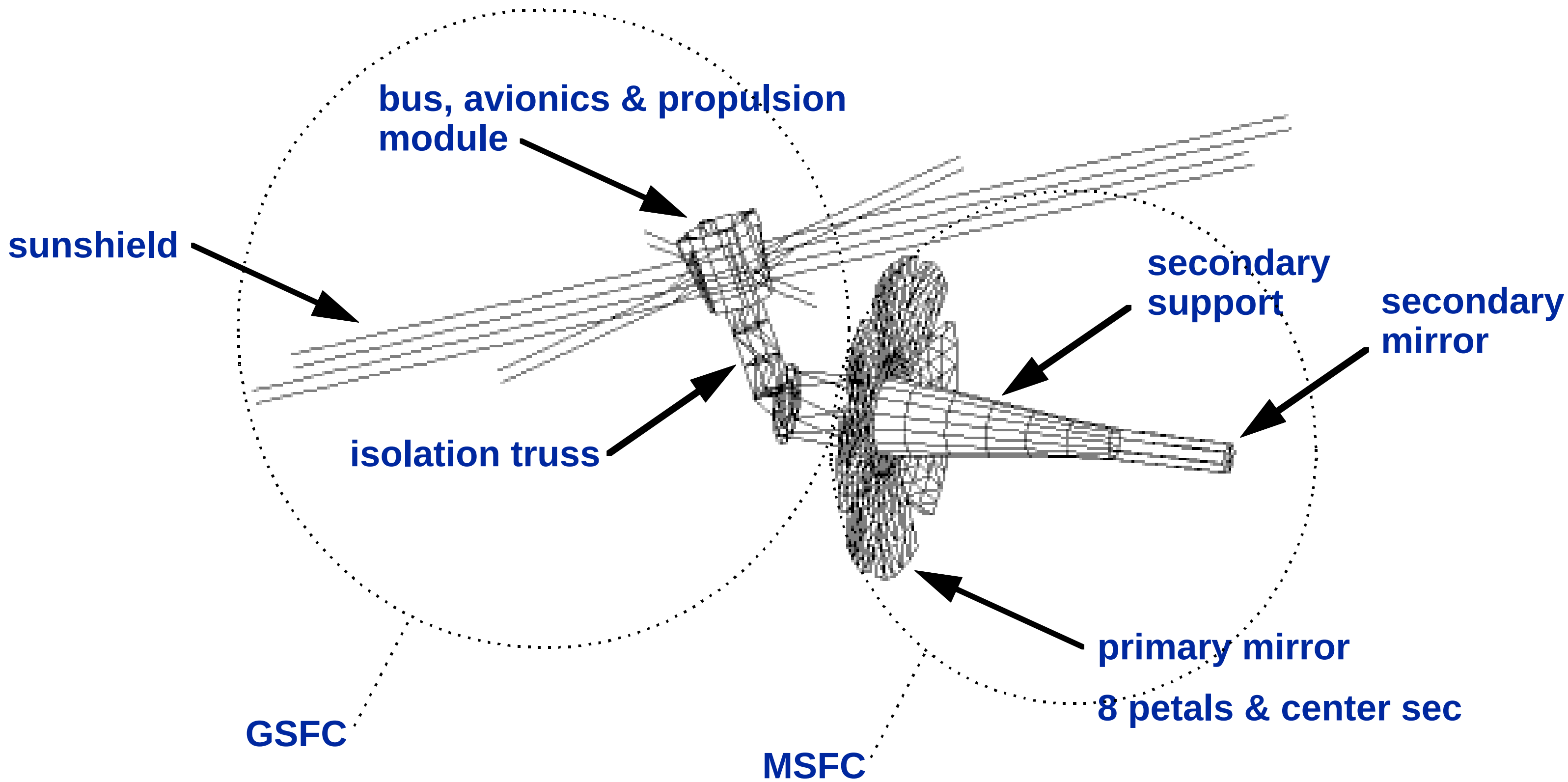
Presentation Outline

- Overview of Using IMOS with NGST
- Identification of NGST Model Components
- Model Simplification
- NGST 6/97 Model Overview
- Model Checkout Results
- Thermal Distortion Analysis
- Using Substructuring for Very Large Models
- Summary of IMOS Experience with NGST

Overview of Using IMOS with NGST (structures):

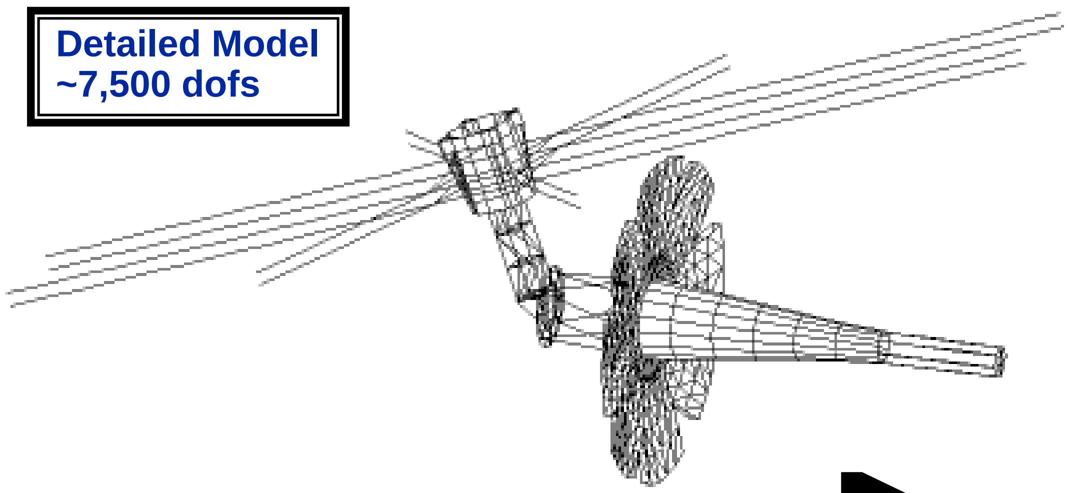
- **Conversion of Integrated NGST NASTRAN Model to IMOS**
  - **initial model simplification of GSFC S/C structure (in NASTRAN)**
  - **conversion using nas2imos (generates k and m)**
- **Eigenvalue Analysis**
  - **first 100 modes (using speig)**
  - **animation of mode shapes (using movmak/movply)**
  - **mode identification using modal strain and kinetic energies**
- **Generation of Modal State Space Models**
  - **assembly of a, b, c, d Matrices (using mode2ss)**
- **Thermal Distortion of Telescope due to Temperature Profile (from MSFC)**
  - **using thermal analysis script (see viewgraph)**
- **Transient Time History Dynamic Simulation (fhist from GSFC)**
  - **using lsim**
  - **animation of response (using movmak/movply)**
- **Parametric Studies of Stiffness Characteristics**

Identification of NGST Model Components



Model Simplification

Detailed Model
~7,500 dofs



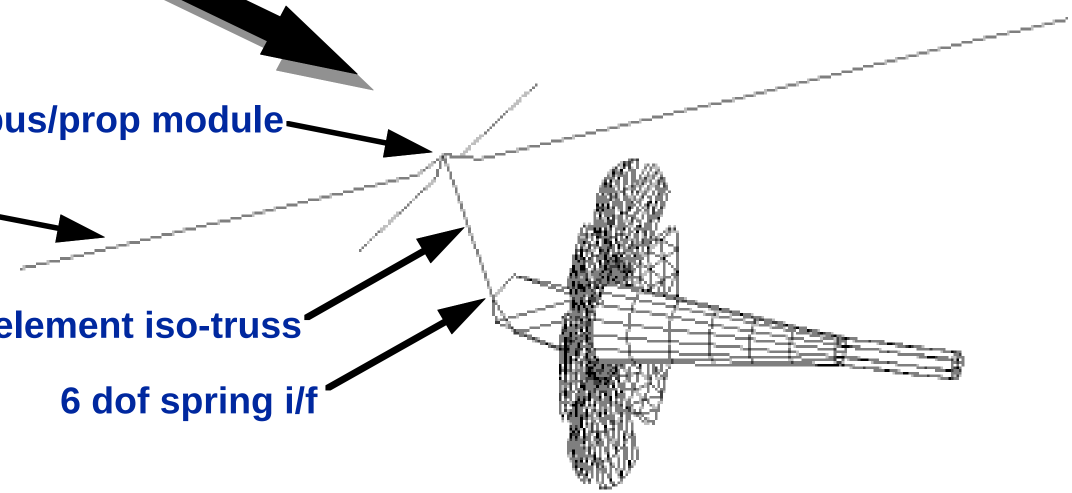
Simplified Model
~5,000 dofs

6 dof pt mass bus/prop module

sunshield arms
8-10 elts ea.

4 element iso-truss

6 dof spring i/f



NGST 6/97 Model Overview

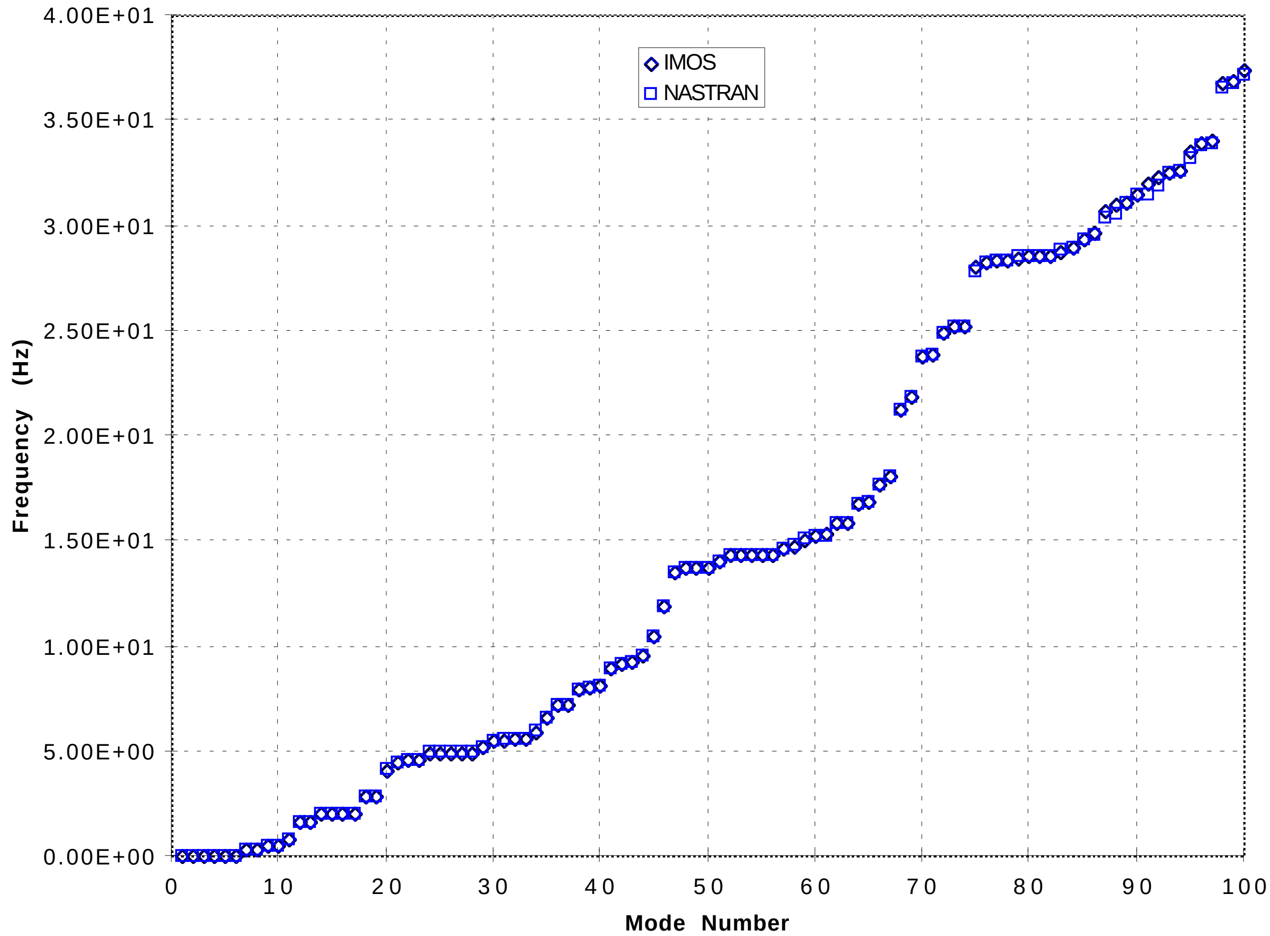
- **Nodes: 904 Total**
  - **5060 Independent Dynamic dofs**
- **Elements: 1335 Total**
  - **beam 485**
  - **conm 134**
  - **celas 6**
  - **plate 648**
  - **rbe2 62**
- **Local Coordinate Systems: 12 Total**
  - **1 Spherical**
  - **1 Cylindrical**
  - **10 Rectangular**
- **Plate Bending and Shear Factors (and Materials) Used in NASTRAN Model**
  - **Representing Honeycomb Sandwich Construction**
  - **Automatic Conversion Using nas2imos**

Model Checkout Results

- **Rigid Body Mode Strain Energy Should be Small**
  - **automatic printout using rbmodesk**
  - **for NGST the largest component was found to be < 1.0e-7**
- **Mass Properties Agree with NASTRAN**
  - **using wtcgk, cg_calck**
  - **Total mass= 2167 kg**
  - **Inertia Matrix about cg**
  - **Center of Gravity [xcg,ycg,zcg]= [-1.7050, -.02746, 1.4915]**
- **Normal Modes Analysis**
  - **free-free boundary conditions (using speig with shifted k)**
  - **frequencies agree with NASTRAN (within 1%, see plot)**
  - **cross orthogonality of IMOS and NASTRAN modeshapes was good**
    - **ideally** $\Phi_{IMOS}{}^{T} * M_{IMOS} * \Phi_{NASTRAN} = I$
    - **found max diff of .01 on diagonal, max .10 off-diag (ave .0005 off-diag)**
- **Transient Dynamic Analysis Response Agrees with NASTRAN (see plot)**

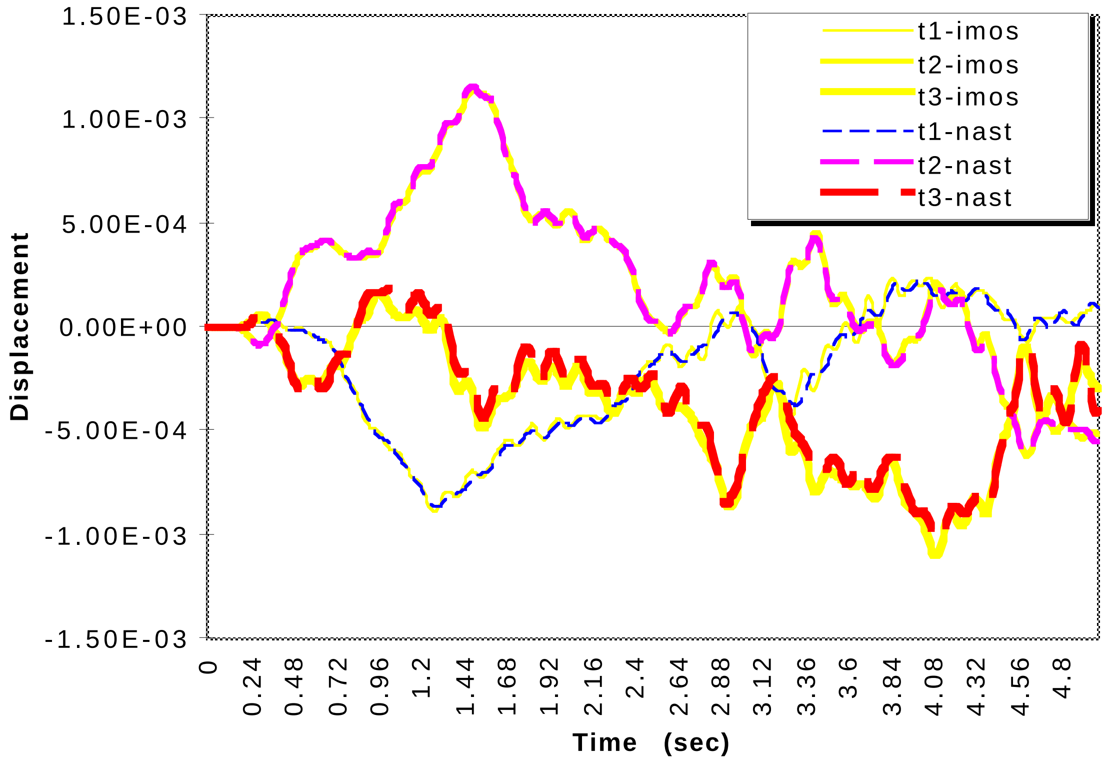
NEXT GENERATION SPACE TELESCOPE STRUCTURAL MODELING & ANALYSIS

Comparison of Modal Frequencies for NASTRAN and IMOS Models (v.6/97)



NEXT GENERATION SPACE TELESCOPE STRUCTURAL MODELING & ANALYSIS

Comparison of NASTRAN and IMOS Transient Response Histories



Thermal Distortion Analysis

- Computed Mirror Distortion Vectors for Applied Temperature Profiles
  - Temperatures provided by MSFC in NASTRAN bulk data format
    - converted to IMOS automatically with nas2imos
  - Steady State Ground to Orbit (used 100 deg K ref)
    - used cte's integrated over temp range
    - subtract ref temp to get delta T
  - Thermal Transient, 1 hr slew with 27 hr hold (43 time steps)
    - no dynamics involved- static response only
    - temps at T=0 used as reference
  - used tplate and tbeam (see viewgraph)
- Viewed Thermal Distortion using modelplot (static) and movmak (animation)
- Compared Thermal Distortions from IMOS with NASTRAN
  - difference is much less than 1%, ($\mathrm{norm}(u_{IMOS} - u_{NASTRAN}) / \mathrm{norm}(u_{NASTRAN})$)
- Thermal Distortion Vectors Transmitted for Optical Performance Analysis

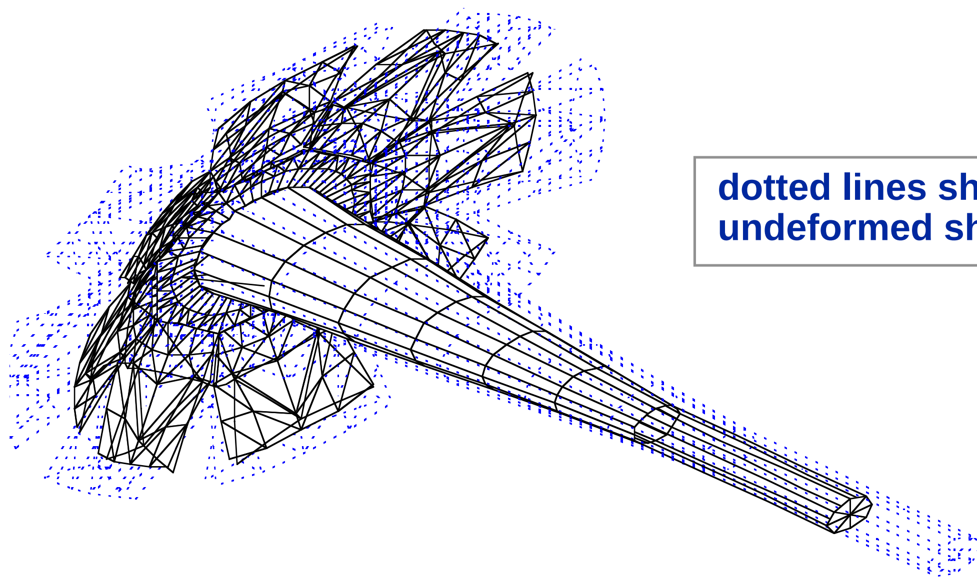
NEXT GENERATION SPACE TELESCOPE STRUCTURAL MODELING & ANALYSIS

Script for Thermal Distortion Analysis

```
% This is a script to compute the displacement vector due to
% a temperature distribution (T) or gta.

niplate=[niquad; nitria];

ftoplate=tplate(niplate,xyz,propplt,mat,[1:length(niplate(:,1))]');
% ftobar=tbeam(nibar,xyz,propbar,[1:length(nibar(:,1))]');
ftobar=tbeam(nibar,xyz,propbar,[1:length(xyz(:,1))]');

%   Use Element temperatures
% etplate=tempvec(niplate,xyz,gta,0.0);
% [etbar,nt]=tempvec(nibar,xyz,gta,0.0);

% pgb=ftoplate*etplate + ftobar*etbar;
% pgb=ftoplate*etplate + ftobar*nt;

%   Use Nodal temperatures- tn2e transforms nodal to elem temps
tn2e=tnode2el(niplate,xyz);
fto=ftoplate*tn2e + ftobar;
pgb=fto*T;

% transform thermal equiv forces from basic to local
t=gentloc(ti,tf);
pgl=t*pgb;
% reduce to nset and fset
if exist('gm')
  pgl(nset,:)=pgl(nset,:) + gm'*pgl(mset,:);
end
pfl=pgl(fset,:);

% compute displacements
phitl=k\pfl;
%phitl=pinv(full(k))*pfl;

% expand to gset
[np,mp]=size(phitl);
phigl=zeros(max(size(xyz))*6,mp);
phigl(fset,:)=phitl;
if exist('gm')
  phigl(mset,:)=gm*phigl(nset,:);
end

% transform to basic
phigb=t'*phigl;
```

Plot of Thermal Distortion

Steady State, Ground to Orbit

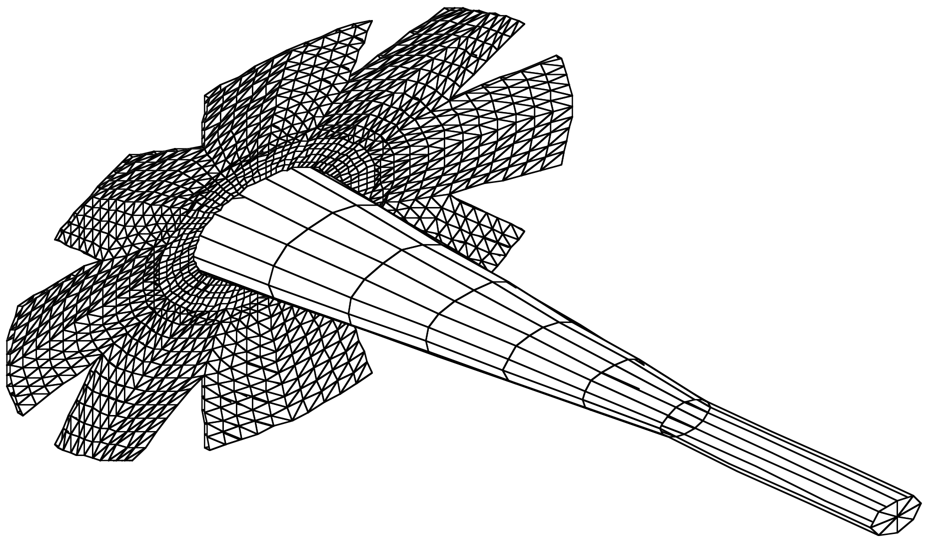


dotted lines show
undeformed shape

Using Substructuring for Very Large Models

- NGST Model with Deformable Glass Primary Mirror has 20,550 dofs
  - Fine mesh required to capture actuator/structure interaction (448 actuators)
    - 36 actuators per petal (8 petals)
    - 160 actuators for central segment
  - Primary mirror model was already simplified
    - actuator spacing increased
- “Out of memory “ when trying to solve large eigenproblem
- Substructuring offered solution

NGST Telescope Model with Glass Primary (v.10/97)



Using Substructuring for Very Large Models

- **Implemented Substructuring- using Craig Bampton method**
  - **divided the structure into 6 parts, taking advantage of symmetry**
    - **central segment pie section (192 boundary dofs)**
      - **found that whole central segment was too big- 6738 dofs**
      - **used 1/8 pie section- 924 dofs for eigenproblem**
    - **petal type 1 (24 boundary dofs) (1584 dofs for eigenproblem)**
    - **petal type 2 (24 boundary dofs) (1584 dofs for eigenproblem)**
    - **secondary mirror & support structure (96 boundary dofs)**
    - **science instrumentation assembly (6 boundary dofs)**
    - **isolation truss, bus/prop module & sunshield (9 boundary dofs)**
  - **used cms_comp_cb.m to perform analysis on each of the 6 parts (see viewgraph)**
    - **compute fixed interface normal modes (eigenvalue analysis)**
    - **compute constraint modes (static)**

Using Substructuring for Very Large Models

Script to generate component mode data for petal type 1 substructure

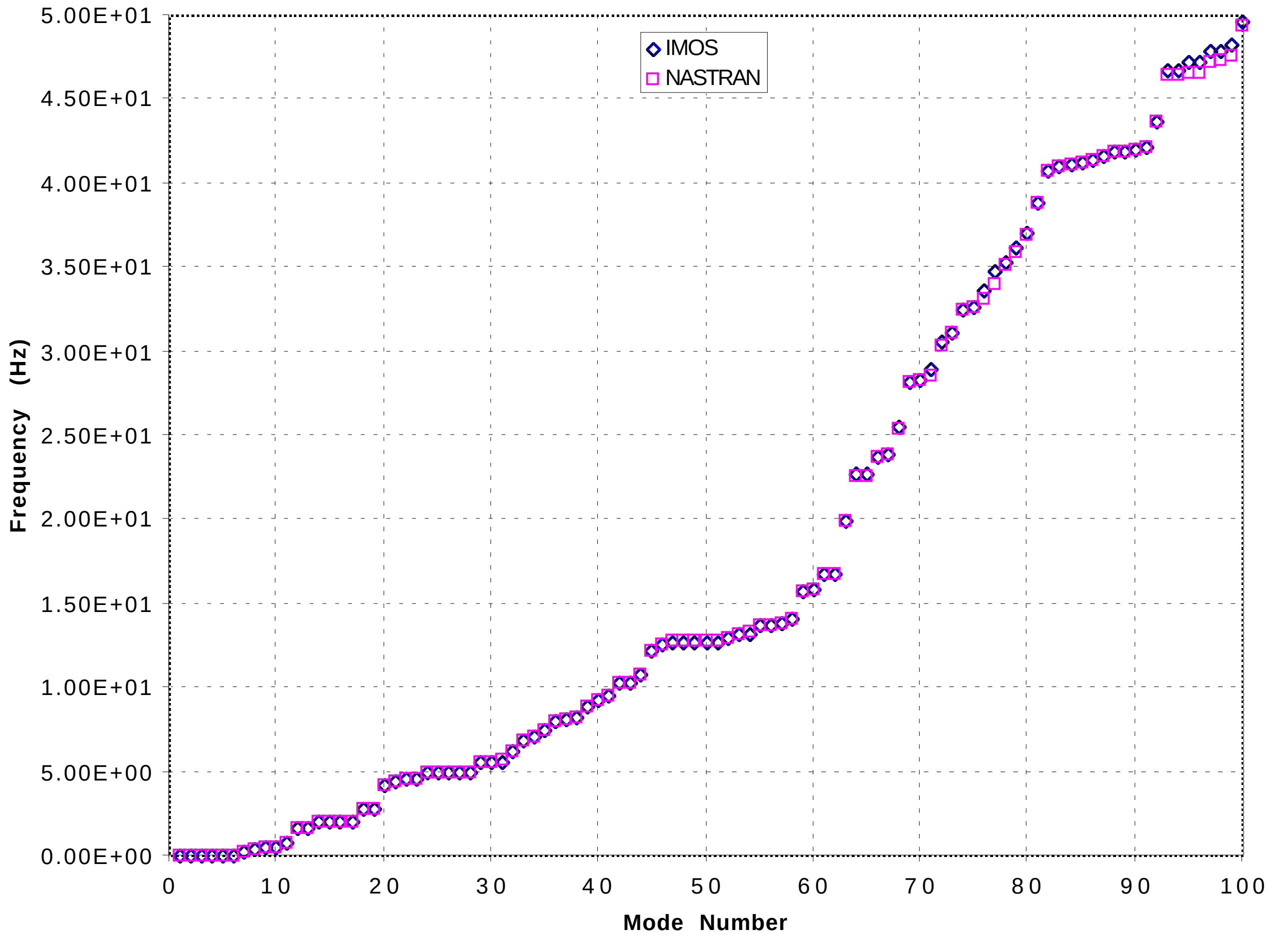
```
echo on
%  define internal i-set and boundary b-set grid groups
ig1=[561:692,2177:2241,2243:2308];
ig1=[ig1'  ones(length(ig1),6)];
bg1=[2097 1 1 1 0 0 0
    2102 1 1 1 1 1 1
    2107 1 1 1 0 0 0
    2242 1 1 1 1 1 1
    3166 1 1 1 1 1 1];

% get active internal and boundary dofs
is1=getdofs(ig1,xyz,bc);
bs1=getdofs(bg1,xyz,bc);

[knn1,kbb1,mnb1,mbb1,p1]=cms_comp_cb(k,m,is1,bs1,100);

% expand p to include dependent dofs, exclude spcs
[p1]=cms_comp_i2d(xyz,p1,ig1,is1,bs1,fset,spcgid,nset,mset,gm);

save petal_1c_cms knn1 kbb1 mnb1 mbb1 p1
```

Using Substructuring for Very Large Models

- Implemented Substructuring- using Craig Bampton method (cont'd)
  - replicated central segment pie section 8 times
  - replicated petal types 1 & 2 - 4 times each
  - total of 19 components assembled (including replications)
  - resulting system eigenproblem size of 2715 dofs
- Comparison of resulting system frequencies between NASTRAN and IMOS
  - frequencies match within 1% (see plot)

NEXT GENERATION SPACE TELESCOPE STRUCTURAL MODELING & ANALYSIS

Comparison of Modal Frequencies for NASTRAN and IMOS Models (Glass v. 10/97) (IMOS model used Substructuring)



Summary of IMOS Experience with NGST

- **Eigenvalue Analysis**
  - **speig sparse eigenvalue solver is slow for large problems**
    - **compiled version would help greatly**
    - **routine specializing in real-symmetric matrices would help too**
    - **have had bad results with small problems (< 1k dofs)**
    - **good results for large problems**
  - **need to check results**
    - **compute residuals from the modal equation**
      - $\Re = K\Phi - M\Phi\Lambda$
      - **compare norm of each modal residual vector with that of** $K\Phi$
        - **can recompute modes in problem frequency range**
    - **check orthogonality, i.e.** $\Phi^T M\Phi$
      - **can re-orthogonalize using onormphi (Gram-Schmidt) or other**
    - **sometimes small imaginary parts show up**
      - **can take real part if imaginary part is small enough**
      - **re-orthogonalize using onormphi**

Summary of IMOS Experience with NGST (contd)

- **Thermal Distortion Analysis**
  - **need to re-check model after every modification**
    - **uniform cte with constant delta T (common sense, but ...)**
- **Substructuring**
  - **tedious up front bookkeeping, but effective method**
    - **subsequent studies using mat changes would be fast**
  - **checking results of system eigen-analysis is essential (see prev viewgraph)**
    - **had to zero in on problem fequency ranges with speig**
  - **can use it for statics as well- just using constraint modes**
- **Overall**
  - **favorable comparisons between IMOS and NASTRAN**
  - **flexibility of working in a MATLAB environment accelerates productivity**
  - **better eigen-solver would be a big help**